

REPORT DOCUMENTATION PAGE			Form Approved OMB No. 0704-0188	
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1. AGENCY USE ONLY (Leave blank)		2. REPORT DATE 8/26/96	3. REPORT TYPE AND DATES COVERED Final, 11/24/94-11/30/95	
4. TITLE AND SUBTITLE Scanning Probe Microscope For Ultra-High Resolution Nanoscale Electron and Near-Field-Optical Lithographies and Metrology			5. FUNDING NUMBERS DAAH04-95-1-0026	
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7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Department of Electrical Engineering University of Minnesota Minneapolis, MN 55455			8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES) U.S. Army Research Office P.O. Box 12211 Research Triangle Park, NC 27709-2211			10. SPONSORING / MONITORING AGENCY REPORT NUMBER  ARO 3376/1-EL-RIP	
11. SUPPLEMENTARY NOTES The views, opinions and/or findings contained in this report are those of the author(s) and should not be construed as an official Department of the Army position, policy, or decision, unless so designated by other documentation.				
12a. DISTRIBUTION / AVAILABILITY STATEMENT  Approved for public release; distribution unlimited.			12b. DISTRIBUTION CODE	
13. ABSTRACT (Maximum 200 words)  We purchased a scanning probe microscope (SPM), that can operate as an atomic force microscope (AFM), a scanning tunneling microscope (STM), and magnetic force microscope (MFM), and have the hardware and software necessary for ultra-high resolution lithography and alignment. The equipment has played a key role to our ongoing research programs in nanostructures and nanodevices sponsored by ARO as well other agencies such as ONR, ARPA, and NSF. Using the instruments, we studied the topologies of a variety of sub-20 nm structures and the magnetic properties of magnetic nanostructures, which are a new material system and can strongly impact future magnetic recording. Finally, we have used the instrument as a lithography tool.				
14. SUBJECT TERMS			15. NUMBER OF PAGES	
			16. PRICE CODE	
17. SECURITY CLASSIFICATION OF REPORT UNCLASSIFIED	18. SECURITY CLASSIFICATION OF THIS PAGE UNCLASSIFIED	19. SECURITY CLASSIFICATION OF ABSTRACT UNCLASSIFIED	20. LIMITATION OF ABSTRACT UL	

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**SCANNING PROBE MICROSCOPE FOR ULTRA-HIGH RESOLUTION  
NANOSCALE ELECTRON AND NEAR-FIELD-OPTICAL  
LITHOGRAPHIES AND METROLOGY  
(DURIP)**

**FINAL REPORT**

STEPHEN Y. CHOU

AUGUST 26, 1996

U.S. ARMY RESEARCH OFFICE

CONTRACT/GRANT NUMBER DA/DAAH04-95-1-0026

DEPARTMENT OF ELECTRICAL ENGINEERING  
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## **I. Objective**

The grant is for purchase of a scanning probe microscope (SPM), that can operate as an atomic force microscope (AFM), a scanning tunneling microscope (STM), and magnetic force microscope (MFM), and have the hardware and software necessary for ultra-high resolution lithography and alignment. The primary use of the system will be for ultra-high resolution metrology of nanostructures and ultra-high resolution nanoscale lithography.

## **II. Summary of Major Accomplishments**

We purchased a scanning probe microscope (SPM) system from Digital Instruments--a company regarded by many to be the best in the business. The system includes a scanning tunneling microscope (STM) head; an multi-mode head that perform atomic force microscopy (AFM) and magnetic force microscopy (MFM); piezoelectrical stages with different scanning ranges; control electronics and computer; and software for operation, image, and data analysis. Because of some practicalities, only \$111,000 was spent and \$29,000 was reverted to government.

The equipment has played a key role to our ongoing research programs in nanostructures and nanodevices sponsored by ARO as well other agencies such as ONR, ARPA, and NSF. We have used the instrument to studied the topologies of a variety of sub-20 nm structures. These structures are very difficulty to investigate using other microscopy technique, therefore deepen our understanding.

Another import application of this instrument is to study the magnetic properties of magnetic nanostructures, which are a new material system and can strongly impact future magnetic recording. Using the instrument, we have a number of first observation of magnetic domain structures in lithographically-patterned magnetic nanostructures. We also used the instrument as a writing head for a new magnetic disk, called "quantized magnetic disk." to demonstrate that the new disk can have a data storage density much higher than that in conventional disk.

Finally, we have used the instrument as a lithography tool and discovered that to making devices the scanning probe-based lithography tool cannot match our existing ultra-high resolution e-beam lithography (This is true for all current commercial scanning probe-based tools).

## **III. List of Publications**

Many research projects in our group have benefited from the instrument. Here we just list a few examples.

- [1] S. Y. Chou, M. S. Wei, and P. B. Fischer, "An Ultra-high Resolution Single-Domain Magnetic Force Microscope Tip Fabricated Using Nanolithography", *IEEE Trans. on Magnetics*, **30**(6), 4485-4487, Nov., 1994.

[2] S. Y. Chou, M. S. Wei, P. R. Krauss, and P. B. Fischer, "Study of Nanoscale Magnetic Structures Fabricated Using Lithography and Quantum Magnetic Disk", *J. Vac. Sci. and Tech.*, **B12**(6), 3695-3698, 1994.

[3] P. R. Krauss, P. B. Fischer, S. Y. Chou, "Fabrication of Single-Domain Magnetic Pillar Array of 35 nm Diameter and 65 Gbits/in<sup>2</sup> Density", *J. Vac. Sci. and Tech.*, **12**(6), 3639-3642, 1994.

[4] E. Leobandung, L. Guo, and S. Y. Chou, "Single Electron and Hole Quantum Dot Transistors Operating above 110K," *J. Vac. Sci. and Tech.*, **B13**(6), 2865-2868, 1995.

[5] S. Y. Chou, and W. Y. Deng, "Subwavelength Amorphous Silicon Transmission Gratings and Applications in Polarizers and Waveplates," *Appl. Phys. Lett.*, **67**(6), 742-744, 1995.

#### **IV. List of Personnel Participating The Scientific Project**

Principal Investigator: Professor Stephen Chou

Member of Nanostructure group

#### **V. Advanced Degrees Awarded to Personnel on the Project**

**M.S. Degree:**

None

#### **VI. Invention Disclosure**

None